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GREY MOULD CONTROL BY SEEDLING CANOPY HUMIDITY REDUCTION THROUGH UNDER-BENCH VENTILIATION AND STYROBLOCK AERATION

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ABSTRACT

The potential for grey mould control on Douglas-fir seedlings was investigated using under-bench ventilation and aerated styroblocks. Standard container-nursery procedures were used to grow coastal Douglas-fir seedlings in unmodified, unvented control styroblocks and in styroblocks with aeration holes at each intercavity intersection and vented with heated forced air, unheated forced air and unheated, unforced air. End of season morphology assessment indicated no difference in seedling heights and root collar diameters between treatments. Twenty-five percent of all ventilated styroblock seedlings were infected with *Botrytis cinerea* while 75% of the control seedlings showed signs of infection. Of all the seedlings showing evidence of grey mould infection, those in the untreated control were most severely affected. The reduced incidence of grey mould in the ventilated treatments was attributed to a more rapid drying of the seedling canopy following watering. The lowest frequency of ideal conditions for *B. cinerea* infection by spore germination was observed in the seedling canopy of the treatment receiving unheated, forced air ventilation.

INTRODUCTION

Grey mould caused by the fungus *Botrytis cinerea* Pers., is a major impediment to the production of container-grown conifer seedlings in British Columbia (Sutherland and Van Eerden 1980). In the nursery, Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco is particularly susceptible to the disease (Sutherland *et al.* 1981). Diseased seedlings are either killed outright or develop an overall lack of vigour which reduces their survival after outplanting. Grey mould losses of 25-30%, encountered during lifting of seedlings can become even higher if *B. cinerea* is carried over to affect cold-stored seedlings.

Grey mould management in container nurseries currently relies heavily on protectant fungicide sprays. However, full-season protectant spray programs are increasingly resulting in yield-loss while also promoting strains of *B. cinerea* that show tolerance to fungicides (Glover 1985).

Grey mould symptoms on container-grown Douglas-fir seedlings usually become evident in late August or early September. However, airborne *B. cinerea* conidia have been observed in container greenhouses 6-8 weeks earlier than this and Douglas-fir seedlings are thought to be susceptible to infection at this time (Peterson *et al.* 1988). Following canopy closure (late-June to mid-July) and after watering via the overhead irrigation boom, free moisture has been observed to persist on seedling foliage for as long as 120 h. This creates conditions optimum for spore germination and infection by conidia of *B. cinerea* (temperature 15-20°C and relative humidity (RH) $\geq$ 98%) (Nelson 1951; Jarvis 1962; Bulit *et al.* 1970; Trolinger

1983). Thus, with a susceptible host and sufficient numbers of spores present to initiate an epidemic, the occurrence of favourable environmental conditions determines the success or failure of grey mould infection on container-grown Douglas-fir seedlings.

Lower seedling canopy humidities combined with reductions in the length of time free moisture persists on seedling foliage would be a desirable way to achieve effective grey mould control. Should this be possible with no adverse morphological effects and no reduction in seedling densities, it may enable effective grey mould management with reductions in fungicide sprays. To evaluate the efficacy of methods of promoting canopy drying following watering and to achieve overall humidity reduction, an experiment was conducted using aerated styroblocks in combination with increased airflow through the seedling canopy.

MATERIALS AND METHODS

The experiment was conducted in a 5200 m^2 polyethylene-covered greenhouse operated by Canadian Pacific Forest Products Ltd., Saanichton, British Columbia. To assess the potential for seedling canopy humidity reduction and foliage drying, coastal Douglas-fir seedlings (seedlot # 968) were sown in June, 1988 and grown in modified styroblocks using standard nursery production procedures (Matthews 1981). Seedlings were grown at a density of 764 seedlings/m^2 in *Econoblock 160* styroblocks on benches 1 m above an asphalt floor. The styroblocks were modified by exposing a 6 mm hole at every intercavity intersection giving a total of 135 holes/styroblock. The holes extended through the entire depth of

the styroblock enabling the promotion of an airflow from below, up through the seedling canopy. Four treatments of 90 styroblocks each were used as follows:

TR1) standard configuration styroblocks (control)

TR2) modified styroblocks with under-bench, heated forced air applied

TR3) modified styroblocks with under-bench, ambient forced air applied

TR4) modified styroblocks with no mechanically forced airflow applied

For TR2 and TR3, the area below the growing bench was enclosed with a skirt of polyethylene. Heated air was applied with the use of three, 1500 W electric fan heaters. Forced air alone was applied with a single fan. A positive airflow was mechanically maintained in TR2 and TR3 for 24 h following the completion of an overhead irrigation cycle. This was done following full canopy closure from August 1988 until December 1988 inclusive.

From August 1988 onwards, microclimatic variables were measured in each treatment. A thermocouple was used to record styroblock cavity temperature near the seedling roots at a depth of 5 cm. Ambient air temperature in each seedling canopy was measured with a thermocouple and relative humidity in the same location was determined using aspirated thermocouple psychrometers. Electrical resistance, needle wetness sensors as described by Sutton *et al.* (1984) were placed in each canopy to indicate canopy wetness duration. The data from all microclimatic sensors were recorded every hour using microprocessor based data loggers (Model 21X, Campbell Scientific, Edmonton, Alberta).

Seedlings were extracted for cold storage in January 1989 at

which time treatment effects on seedling morphology and grey mould control were examined. One treatment replicate consisted of 13 styroblocks, each containing 160 seedlings. Treatments were replicated four times for a total of 52 styroblocks/treatment. To assess morphological effects, seedling height (from root collar to bud tip) and stem diameter (at root collar) were measured. Three seedlings were extracted from each styroblock for a total of 39 seedlings/replicate. All data were analyzed using PC SAS on an IBM microcomputer.

Following the morphological measurements, ratings of grey mould incidence and disease severity were determined for each styroblock within a replicate as follows:

Disease incidence

Rating	Percent seedlings affected/styroblock
1	0 - 25%
2	26 - 50%
3	51 - 75%
4	76 - 100%

Disease severity

Rating	Disease severity
1	Very light (few bottom needles affected)
2	Light (lower needles affected)
3	Light-moderate (lower 25% seedling affected)
4	Moderate (lower 33% seedling affected)
5	Moderate-severe (lower 66% seedling affected)
6	Severe (entire seedling affected or dead)

Seedling morphological characteristics and microclimatic data were normally distributed as indicated by Chi-square. These data were subjected to a one way analysis of variance (ANOVA) and Tukey's studentized range test was used to indicate differences between treatments.

Disease incidence and severity were examined separately. A Chi-square test indicated the data were not normally distributed. Thus, the data were ranked and an ANOVA performed on the ranked values, equivalent to a Kruskal Wallis nonparametric analysis of variance (Zar 1984). Tukey's studentized range test was applied to the ranked data to indicate significant differences between treatments.

RESULTS

Average cavity soil temperatures from August to December during periods when no heated or forced air treatments were being applied and also during the times when venting was being carried out are shown in Table 1. A one way ANOVA showed no significant difference between cavity soil temperatures among treatments during times without venting ($P=0.0001$, $F=42.19$, $df_n=3$, $df_d=9994$) and also during the times venting was being carried out ($P=0.0001$, $F=55.14$, $df_n=3$, $df_d=1120$). However, Tukey's studentized range test showed the soil temperatures in TR2 to be significantly higher than those in the other treatments during times when under-bench heat was being applied ($P=0.01$, $df=1120$).

Temperature and humidity conditions optimum for infection by B.

cinerea spore germination were observed in each treatment canopy from August to October inclusive (Table 2). Temperature and humidity conditions favouring grey mould infection by spore germination were not observed during November and December.

Table 1. Mean cavity soil temperatures from August to December during the times of no forced air venting and during times when active venting was being carried out.

	Cavity soil temperature °C.	
Treatment	No active venting	Active venting
TR1	12.7	13.3
TR2	13.4	18.1*
TR3	13.4	13.1
TR4	14.4	13.4

* Significantly different at P=0.01

Table 2. Days per month with optimum conditions for infection by *B. cinerea* spore germination (Temperature 15-20°C and RH $\geq$ 98%) and the mean hours per day those conditions prevailed in each treatment.

	TR1		TR2		TR3		TR4	
Month	Days	Mean h/day	Days	Mean h/day	Days	Mean h/day	Days	Mean h/day
August	10	3.7	5	4.6	2	1	5	3.2
September	7	2.4	7	2.9	3	1.3	7	2.3
October	4	1.5	4	3.3	2	1.5	4	1.5

Average canopy air temperatures from August to December during periods when no heated air treatments were being applied and during times when venting was being carried out are shown in Table 3. A

one way ANOVA showed no significant difference between canopy air temperatures among treatments during times without venting ($P=0.0001$, $F=45.06$, $df_n=3$, $df_d=9995$) and also during the times venting was being carried out ($P=0.0001$, $F=21.34$, $df_n=3$, $df_d=1120$). During the times under-bench heat was being applied, Tukey's studentized range test indicated TR2 to have a mean canopy air temperature significantly higher than the other treatments ($P=0.01$, $df=1120$).

Table 3. Mean canopy air temperatures from August to December during the times of no forced air venting and during times when active venting was being carried out.

	Canopy air temperature °C	
Treatment	No active venting	Active venting
TR1	12.5	12.8
TR2	12.7	15.9*
TR3	13.1	13.0
TR4	14.3	12.9

* Significantly different at $P=0.01$

From August to December, average RH's in each canopy during periods when no heated or forced air treatments were being applied and during times when venting was being carried out are shown in Table 4. A one way ANOVA showed no significant differences in RH during the times without venting ($P=0.0001$, $F=33.59$, $df_n=3$, $df_d=9995$) or during the times active venting was being carried out ($P=0.0001$, $F=8.47$, $df_n=3$, $df_d=1123$). Tukey's studentized range test showed TR1 to have a significantly higher RH than the other treatments during the times venting was not being carried out and

that TR2 had a significantly lower RH than the other treatments when venting was being conducted (P=0.01, df=1120).

Table 4. Mean canopy relative humidities from August to December during the times of no forced air venting and during times when active venting was being carried out.

	Relative Humidity %	
Treatment	No active venting	Active venting
TR1	91.6*	95.6
TR2	89.9	92.5*
TR3	89.0	95.5
TR4	88.8	95.4

* Significantly different at P=0.01

Relative lengths of canopy wetness duration, indicated by mean needle wetness are shown for 120 h following water shut off (Figure 1). On average, needles remained wet following watering for 18, 28, 29, and 86 hours in TR2, TR4, TR3, and TR1 respectively. From August to December, no significant variation between needle wetness among treatments was indicated by the ANOVA (P=0.0001, F=91.12, df_n=3, df_d=3356). Tukey's studentized range test indicated TR1 with a mean needle wetness value of 0.55 to be significantly higher than the other three treatments (P=0.01, df=3356). Mean needle wetness in TR2 was 0.29, significantly lower than all of the others (P=0.01, df=3356).

Mean seedling heights and root collar diameters as measured in January 1989 are shown in Table 5. No significant variation between

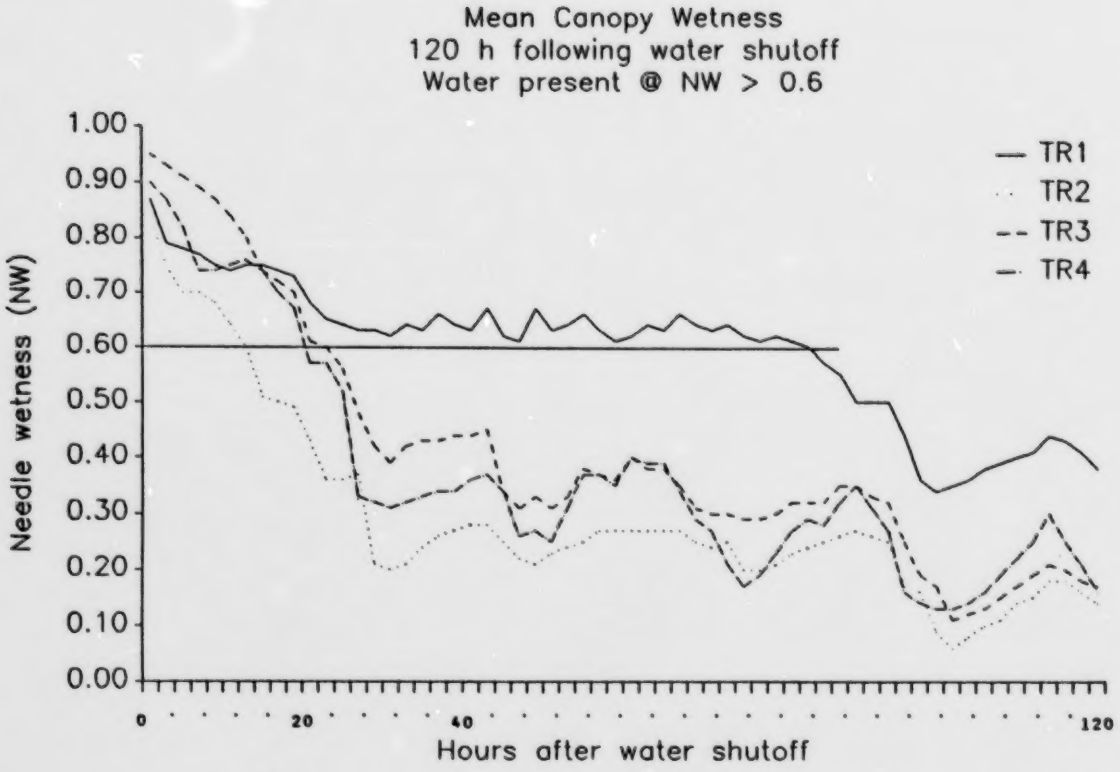

Figure 1. Mean seedling canopy needle wetness for 120 h after water shut off in TR1, TR2, TR3, and TR4 seedling canopies.

seedling heights among treatments was indicated by the ANOVA (P=0.0001, F=10.68, df_n=15,) however, significant variation was indicated between root collar diameters (P=0.477, F=0.98, df_n=15, df_d=608). Tukey's studentized range test showed TR1 seedlings to be significantly higher than the others (P=0.01, df=608) while the same test showed no significant difference between root collar diameters among treatments (P=0.01, df=608).

Table 5. Mean seedling heights and root collar diameters as measured in January 1989.

Treatment	Seedling measurement	
	Height cm.	Root collar diameter mm.
TR1	23.6*	2.38
TR2	22.3	2.53
TR3	21.8	2.37
TR4	21.9	2.40

* Significantly different at P=0.01

Mean disease incidence rating for TR1 was 3.1, indicating > 75% of the seedlings were affected by grey mould. In the three vented treatments, 25% of the seedlings showed signs of *B. cinerea* infection. Of the infected seedlings, those in TR1 had a mean severity rating between light and light-moderate. All affected seedlings in the three vented treatments showed a mean severity rating of very light. A one way ANOVA of ranked disease incidence ratings indicated no significant differences among treatments ($P=0.0001$, $F=100.6$, $df_a=3$, $df_d=204$). Tukey's studentized range test on the ranked data showed TR1 disease incidence to be significantly higher than those of the other three treatments ($P=0.01$, $df=204$). No significant difference was indicated between grey mould incidence in TR2, TR3, or TR4. Analysis of variance on ranked severity ratings showed no significant differences among treatments ($P=0.0001$, $F=14.86$, $df_a=3$, $df_d=204$). Tukey's studentized range test showed grey mould severity to be ranked significantly higher on TR1 than on the other three treatments. ($P=0.01$, $df=204$). Disease

severity on TR3 was ranked significantly higher than on TR2 and TR4 (P=0.01, df=204). No significant difference in disease severity rank was indicated between TR2 and TR4 (P=0.01, df=204).

DISCUSSION

Styroblock aeration and seedling canopy venting significantly reduced the incidence and severity of grey mould on container-grown Douglas-fir. This was achieved while minimizing the times with elevated soil and canopy air temperatures. Although mean cavity and air temperatures in seedling canopies heated from below can rise significantly higher than those vented with cool air, they remain elevated for only 24 h immediately following watering. These short periods with high soil and air temperatures appear to have no adverse affect on seedling morphology.

The least amount of time with ideal conditions for *B. cinerea* infection by spore germination was encountered when ventilating with cool air. This suggests it to be a preferred method over heat application for seedling foliage drying. Under-bench heat raises canopy air temperature promoting rapid evaporation of moisture from seedling needles. This tends to elevate canopy temperature and humidity into the optimum spore germination range, especially later in the season when the under-bench heat can move ambient canopy air temperatures from below 15°C, into the 15-20°C range. The recommendation to use cool air venting is further supported by the evidence of disease incidence and severity. Grey mould incidence was not significantly different among the three vented treatments while the severity of infection on the cool air vented seedlings, although

statistically higher than on the other two was of no practical significance.

The highest incidence and severity of grey mould on the unvented control seedlings was a direct result of the longer time needed to dry the canopy after watering. The seedling canopy that received hot air venting was dry an average of 68 h before that in the unvented control while the cool air vented canopy was dry 57 h before the control. As no practical difference between grey mould incidence and severity among the three vented treatments was observed, this also suggests that it may be best to vent the styroblocks using cool air. The extra 11 h required to dry the canopy using cool, compared to heated air will be offset by a reduction in hours with ideal atmospheric conditions (temperature 15-20°C with RH $\geq$ 98%) for *B. cinerea* infection by spore germination.

This study presents data indicating styroblock aeration and seedling canopy venting with cool air, will significantly reduce the incidence and severity of grey mould on Douglas-fir seedlings. Grey mould control can be achieved in this manner without adversely affecting seedling morphology. It is anticipated that vented styroblocks can benefit all seedling species grown in containers, however, the study was relatively small and confined to a single Douglas-fir seedlot. Thus, future research should examine the effects of styroblock aeration and seedling canopy venting on a larger scale and with other tree species such as western hemlock, *Tsuga heterophylla* (Raf.) Sarg.

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